Research Article

Interval training elicits higher enjoyment versus moderate exercise in persons with spinal cord injury

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Background: High intensity interval training (HIIT) is a robust and time-efficient approach to improve multiple health indices including maximal oxygen uptake (VO_2max). Despite the intense nature of HIIT, data in untrained adults report greater enjoyment of HIIT versus continuous exercise (CEX). However, this has yet to be investigated in persons with spinal cord injury (SCI).
Objective: To examine differences in enjoyment in response to CEX and HIIT in persons with SCI.
Design: Repeated measures, within-subjects design.
Setting: University laboratory in San Diego, CA.
Participants: Nine habitually active men and women (age = 33.3 ± 10.5 years) with chronic SCI.
Intervention: Participants performed progressive arm ergometry to volitional exhaustion to determine VO_2peak. During subsequent sessions, they completed CEX, sprint interval training (SIT), or HIIT in randomized order.
Outcome Measures: Physical activity enjoyment (PACES), affect, rating of perceived exertion (RPE), VO_2, and blood lactate concentration (BLa) were measured.
Results: Despite a higher VO_2, RPE, and BLa consequent with HIIT and SIT ($P < 0.05$), PACES was significantly higher ($P = 0.03$) in response to HIIT (107.4 ± 13.4) and SIT (103.7 ± 12.5) compared to CEX (81.6 ± 25.4). Fifty-five percent of participants preferred HIIT and 45% preferred SIT, with none identifying CEX as their preferred exercise mode.
Conclusion: Compared to CEX, brief sessions of submaximal or supramaximal interval training elicit higher enjoyment despite higher metabolic strain. The long-term efficacy and feasibility of HIIT in this population should be explored considering that it is not viewed as more aversive than CEX.

Keywords: Paralysis, Physical activity enjoyment, Arm ergometry, Oxygen uptake, Affect

Introduction

Spinal cord injury (SCI) presents severe physiological, psychological, and financial challenges to the affected individual. Data[1] report that incidence of new SCI in the United States has increased to approximately 12,500 cases per year. One serious consequence of SCI is impaired locomotion which leads to a relatively sedentary lifestyle and increased risk of chronic disease.[2] In fact, only 50% of persons with SCI obtain an adequate amount of physical activity.[3] As physical activity is a contributing factor affecting chronic disease risk in able-bodied adults[4] as well as in individuals with SCI,[5] identifying optimal exercise modes in SCI is paramount to improve overall health status.

Popular modalities of exercise typically completed by people with SCI include aerobic exercise,[6] resistance training,[7] leisure sports (tennis, basketball, etc.), and wheeling.[3] Advantages to these modalities are that they are more accessible than those used in specialized rehabilitation centers such as locomotor training,[8] functional electrical stimulation,[9] or vibration exercise[10] which are expensive and require guidance of trained personnel. Regular participation in these modalities satisfies exercise-based recommendations for persons with SCI[11] and likely helps them reduce severity of various long-term health related complications after SCI. Nevertheless, beyond the importance of accessibility of exercise for this population or specific benefits to

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health status and physical function is the level of pleasure and enjoyment experienced[12] which may be related to long-term adherence[13] and likely beneficial changes to health status. Nevertheless, to our knowledge, little data exist regarding these indices in SCI. Consequently, much remains to be learned regarding attitudes and perceptions of exercise of various modalities and intensities in individuals with SCI.

In the last decade, high intensity interval training (HIIT) has been shown to be a suitable alternative to moderate continuous exercise (CEX) for significantly improving cardiorespiratory fitness (VO_2max),[14] fat utilization,[15] and insulin sensitivity[16] which overall increases health status and exercise tolerance. HIIT is characterized by completion of repeated bursts of exercise (60–240 seconds in duration) at intensities approaching or equal to the workload associated with maximal oxygen uptake (Wmax) which typically elicit 80–100 percent maximal heart rate. A more intense form of HIIT is sprint interval training (SIT) typically characterized by repeated 10–30 s efforts at power outputs ranging from 170–300% Wmax. Each bout is followed by recovery, with total training duration lower than that of CEX. As time is often cited as the greatest barrier to habitual exercise,[17] this seems advantageous to all individuals. In fact, there are reports that persons with diabetes,[18] heart disease,[19] and obesity[20] can perform HIIT without any side effects while experiencing robust adaptations such as increases in cardiorespiratory fitness and insulin sensitivity typically associated with CEX. More recently, acute bouts of HIIT have been reported to be more enjoyable than CEX in active men[21] as well as untrained adults[22] which highlight its potential in other deconditioned populations such as SCI. To our knowledge, only two studies have examined efficacy of HIT in persons with SCI,[23,24] and data show that men with chronic SCI are quite tolerant of HIIT and experience significant increases (+ 20–24%) in cardiorespiratory fitness in response to HIIT.

This study aimed to compare physiological and perceptual responses between CEX and two widely-utilized modalities of interval training (HIIT and SIT) in persons with SCI. Data will add to the dogma concerning identifying effective exercise-based recovery options to improve physical function, exercise adherence, and health status in this population. It was hypothesized that persons with SCI will view both forms of interval training as being more enjoyable than CEX.

Methods

Participants

Men and women who were habitually active (8.1 ± 4.4 hours/wk) and at least 12 months post-SCI were recruited for this study from a local SCI rehabilitation facility as well as through word-of-mouth. They regularly participated in exercise modalities including wheeling, resistance training, locomotor training, surfing, stretching, and assisted/unassisted walking, yet none had previously performed HIIT. Two had tetraplegia and eight had paraplegia. Prospective participants were free of disease and any musculoskeletal ailment preventing them from completing exercise required in this study. Inclusion criteria were injury lower than C2 and non-ventilator dependent, physician permission to engage in intense exercise, lack of medication use which may affect psychological and physiological responses as measured in the study, and age 18–60 years. Participants initially completed a health-history questionnaire and physical activity survey[25] to verify their eligibility and subsequently provided written informed consent. All study procedures were approved by the University Institutional Review Board.

Experimental design

Participants completed four exercise sessions in the laboratory over a 2–3-week period. All sessions were held at the same time of day within participants and were preceded by a 3-hour fast and abstention from exercise for 24 hours. On the first day, peak oxygen uptake (VO_2peak) was determined during progressive arm ergometry to exhaustion. The subsequent three sessions consisted of CEX, HIIT, or SIT, whose order was randomized. A minimum of 2 days and a maximum of 7 days separated each trial. During these sessions, gas exchange data, blood lactate concentration, and perceptual responses were measured.

Assessment of peak oxygen uptake (VO_2peak)

Participants arrived at the lab dressed in exercise attire for initial determination of VO_2peak. They self-reported their height and body mass, and following 5 minutes of seated rest, pre-exercise blood lactate concentration (BLa) was obtained from a fingertip blood sample (Nova Biomedical, Waltham, MA, USA). After a 5-minute warmup at 7 W, individuals performed arm cranking on the wall-mounted ergometer (Lode Angio, Groningen, the Netherlands) for 8–12 minutes at a self-selected cadence until volitional exhaustion, which was identified as cadence less than 30 rev/minute. The height of the arm ergometer was established during this trial and maintained within participants for all subsequent trials, so the shoulder joint was horizontal to the arm cranks. During exercise, power output was increased in a ramp-like manner by 3 W/minute for persons with tetraplegia and 13 W/minute for persons with paraplegia, and pulmonary gas exchange data were obtained via a metabolic cart (ParvoMedics True One, Sandy, UT, USA) which was calibrated prior to exercise according to manufacturer specifications. Three minutes after this bout, BLa was determined. After an 8–10-minute active recovery at 7 W, participants exercised at 105% of their maximum workload (Wmax) until exhaustion to ensure that VO_2peak was attained in the initial trial. This bout also served to familiarize participants with HIIT to be completed in subsequent sessions.

Completion of CEX, HIIT, and SIT

These sessions were performed in randomized order according to a Latin Squares design.[26] All sessions began with a 5-minute warmup at 10% Wpeak. Continuous exercise consisted of 25 min of arm cranking at 45%Wpeak. HIIT was comprised of eight 60-second bouts at 70% Wpeak separated by 90 seconds of active recovery at 10% Wpeak, while SIT required eight 30-second “all-out” efforts at 105% Wpeak separated by 120 seconds of active recovery at 10% Wpeak.

During all bouts, pulmonary gas exchange data and heart rate (HR, Polar, Woodbury, NY, USA) were continuously obtained every 15 seconds. Values for VO_2 and HR were averaged from three successive values at rest, at the end of the warm-up, and at 25, 50, 75, and 100% of session completion. This represented minutes 5, 10, 15, and 20 for HIIT/SIT and 6.25, 12.5, 18.75, and 25.0 for CEX, respectively. Blood lactate concentration was measured pre-exercise as well as at 25, 50, 75, and 100% of session completion (3 minutes post-exercise). As participants were using their hands to crank the ergometer, at each time point they briefly stopped cranking with one hand and a fingertip blood sample was immediately acquired from the non-exercising limb.

The following psychological measures were also acquired prior to exercise and at 25, 50, 75, and 100% of session completion as well as at 5 minutes post-exercise: rating of perceived exertion (0–10 Category Ratio scale (CR-10)),[27] affect (11-point scale, ranging from +5 very good to –5 very bad),[28] and exercise enjoyment (1–7 scale).[29] These measures were recorded throughout CEX and at the termination of individual HIIT and SIT bouts to better reflect the perception of exercise rather than the transition into recovery. Specific instructions were read to each participant before each session. The meaning of the CR-10 scale was communicated by instructing participants to report perceptions of their exertion in terms of their breathing, heart rate, and level of fatigue. For affect, they were read the following text: *While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable; whereas, others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise*. For exercise enjoyment, they were instructed to *use the following scale to indicate how much you are enjoying this exercise session at this instant*. Participants were asked to respond to each scale in terms of how they felt at that moment. In addition, at cessation of each session, participants were requested to list specific words to describe each modality of exercise.

Ten minutes post-exercise, the Physical Activity Enjoyment Scale (PACES)[30] was completed to assess level of enjoyment of each bout. This instrument contains 18 questions scored on a 1–7 Likert scale. After completion of all three sessions, participants were asked which modality of exercise they ultimately preferred (HIIT, SIT, or CEX).

Data analysis

Data are reported as mean ± standard deviation (SD) and were analyzed with SPSS version 20.0 (IBM Corp, Armonk, NY, USA). Two-way ANOVA with repeated measures was used to examine differences in variables across exercise bout (CEX, HIIT, and SIT) and time. One-way ANOVA with repeated measures was used to identify differences in PACES between bouts. If a significant F ratio was obtained, Tukey’s *post hoc* test was used to identify differences between means. The Greenhouse-Geisser correction was used to account for the sphericity assumption of unequal variances across groups. Effect size was determined using partial eta-squared (η_p^2). Statistical significance was set at $P < 0.05$.

Results

One male participant completed the VO_2peak test and then suffered an unrelated injury, so withdrew from the study. Descriptive characteristics of the eight men and one woman with SCI who completed all requirements of the study are shown in Table 1. Session duration differed between CEX (30 min) and HIIT/SIT (25 min) and total energy expenditure was higher ($F_{2,16} = 13.1$, $P < 0.001$, $\eta_p^2 = 0.62$) in CEX (118.1 ± 37.8 kcal) versus HIIT (102.0 ± 35.2 kcal) and SIT (96.6 ± 31.6 kcal).

Table 1 Participant physical characteristics.

Participant	Age (yr)	DOI (yr)	Injury level	BMI (kg/m^2)	VO_2max (L/min)
F	28	12.0	T2	19.0	0.67
M	57	20.0	C5	22.2	0.66
M	25	1.1	T6	21.7	1.23
M	40	1.1	T9	22.2	1.86
M	27	2.2	T3	22.9	1.27
M	36	10.0	C5	21.5	1.15
M	25	1.4	T5	22.7	1.94
M	27	10.0	T7	22.4	1.55
M	26	3.5	T3	20.8	1.00
Mean ± SD	33.3 ± 10.5	6.8 ± 6.2	NA	22.6 ± 3.1	1.30 ± 0.45

F, female; M, male; DOI, duration of injury; T, thoracic; C, cervical; BMI, body mass index.

Differences in VO_2 and HR in response to HIIT, SIT, and CEX

Oxygen uptake (VO_2) was significantly different across time ($F_{1.1,8.7} = 51.1$, $P < 0.001$, $\eta_p^2 = 0.86$), and a significant main effect ($F_{1.3,10.3} = 4.9$, $P = 0.04$, $\eta_p^2 = 0.38$) and boutXtime interaction ($F_{1.9,15.6} = 3.3$, $P = 0.03$, $\eta_p^2 = 0.29$) were observed. Post hoc analyses showed higher VO_2 in HIIT versus CEX at 75% of session duration and at end-exercise, when VO_2 was higher in response to HIIT and SIT versus CEX (Fig. 1A). Significant differences in HR were seen across time ($F_{1.3,10.0} = 102.0$, $P < 0.001$, $\eta_p^2 = 0.92$) as well as a significant main effect ($F_{1.7,13.3} = 7.0$, $P = 0.01$, $\eta_p^2 = 0.47$) and boutXtime interaction ($F_{3.7,29.8} = 6.1$, $P = 0.001$, $\eta_p^2 = 0.43$). At all exercise time points, HR was higher in SIT/HIIT versus CEX (Fig. 1B). During HIIT and SIT, HR surpassed 90% of peak values.

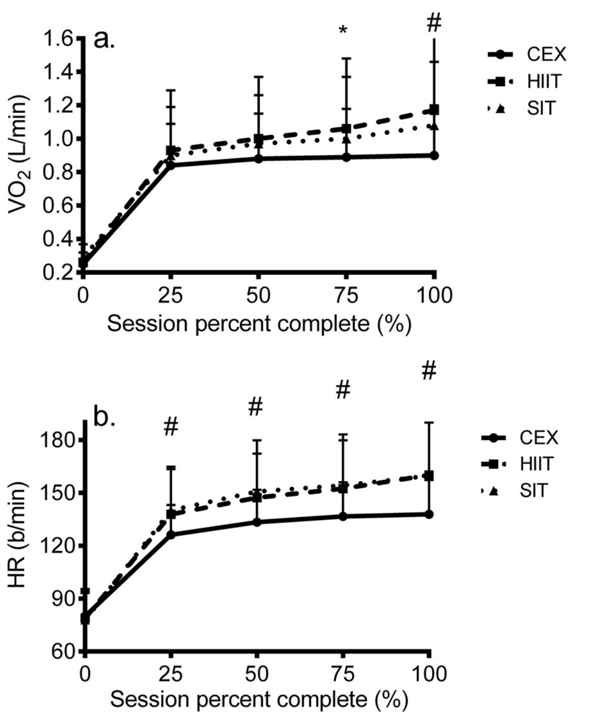

Figure 1 Differences in a) oxygen uptake and b) heart rate in response to sessions of CEX, HIIT, and SIT in persons with SCI. Data are mean ± SD. * = P < 0.05 between HIIT and CEX; # = P < 0.05 between HIIT/SIT and CEX.

Differences in BLa in response to HIIT, SIT, and CEX

Blood lactate concentration was significantly different across time ($F_{1.6,12.7} = 36.7$, $P < 0.001$, $\eta_p^2 = 0.82$) and bouts ($F_{2,16} = 16.2$, $P < 0.001$, $\eta_p^2 = 0.67$), and data showed a significant boutXtime interaction ($F_{3.5,28.9} = 11.6$, $P < 0.001$, $\eta_p^2 = 0.59$). Post hoc analyses revealed that BLa was different at 25% (SIT vs. CEX), at 75% (HIIT and SIT vs. CEX), and at 50 and 100% (HIIT vs. SIT vs. CEX) of session duration (Fig. 2).

Differences in physical activity enjoyment in response to HIIT, SIT, and CEX

Figure 3 reveals differences in PACES between bouts. PACES was significantly different ($F_{1.0,8.2} = 6.7$, $P = 0.03$, $\eta_p^2 = 0.46$), with post hoc analyses demonstrating that SIT (103.7 ± 12.5) and HIIT (107.4 ± 13.4) revealed higher enjoyment versus CEX (81.6 ± 25.4). Across all participants, 5/9 (55%) preferred HIIT and

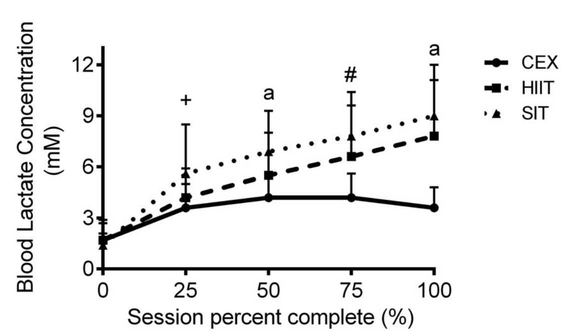

Figure 2 Differences in blood lactate concentration in response to sessions of CEX, HIIT, and SIT in persons with SCI. Data are mean ± SD. + = P < 0.05 between SIT and CEX; # = P < 0.05 between HIIT/SIT and CEX; a = P < 0.05 between all modes.

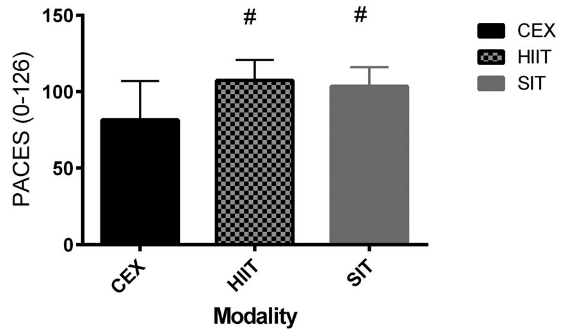

Figure 3 Differences in Physical Activity Enjoyment in response to sessions of CEX, HIIT, and SIT in persons with SCI. Data are mean ± SD. # = P < 0.05 versus CEX.

4/9 (45%) preferred SIT, with no subject citing preference for CEX. All participants reported that HIIT and SIT were "challenging" and/or "energizing," and 66% characterized these modes as "exhilarating and stimulating"; whereas, six participants described CEX as "boring" and "monotonous" with only two participants describing it as "enjoyable" or "stimulating."

Differences in RPE, affect, and exercise enjoyment in response to HIIT, SIT, and CEX

Rating of perceived exertion differed significantly across time ($F_{1.5,11.6} = 120.7$, $P < 0.001$, $\eta_p^2 = 0.94$) and bout ($F_{2,16} = 9.7$, $P = 0.02$, $\eta_p^2 = 0.55$). A significant boutXtime interaction was observed ($F_{10,80} = 3.7$, $P < 0.001$, $\eta_p^2 = 0.32$). Post hoc analyses showed that RPE during HIIT and SIT was higher than CEX at 50, 75, and 100% of session duration (Fig. 4A). Affect declined across time ($F_{1.7,13.5} = 3.9$, $P = 0.049$, $\eta_p^2 = 0.33$) but no main effect of bout ($P = 0.23$) or boutXtime interaction ($P = 0.51$) was demonstrated (Fig. 4B). Affect measured 5 min post-exercise was more positive ($P < 0.05$) than all exercise values and was similar to the pre-exercise value. Exercise enjoyment gradually increased during exercise from baseline but this failed to reach significance ($P = 0.53$) (Fig. 4C). In addition, no main effect of bout ($P = 0.09$) or boutXtime interaction ($P = 0.52$) was revealed.

Discussion

Completion of acute bouts of high intensity interval training elicits higher enjoyment compared to continuous exercise in active[20] and untrained adults.[21] Due to its robust physiological adaptations[13,14,17] as well as lower training volume which may reduce exercise duration, HIIT seems to be an attractive alternative to CEX in various populations. Nevertheless, its potential in persons with SCI is poorly understood and no study has explored differences in enjoyment between HIIT

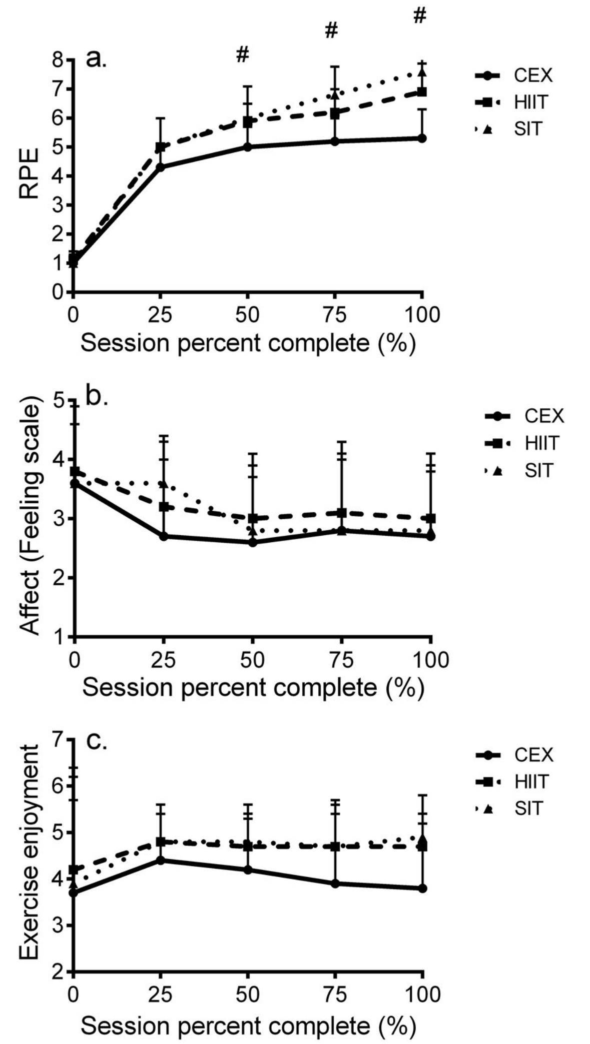

Figure 4 Differences in A) ratings of perceived exertion, B) affect, and C) exercise enjoyment in response to sessions of CEX, HIIT, and SIT in persons with SCI. Data are mean ± SD. # = P < 0.05 between HIIT/SIT and CEX.

and CEX in this population. Our data show that enjoyment as measured with the PACES scale was significantly higher in response to HIIT and SIT compared to CEX despite intensity of HIIT surpassing 90% HRpeak. In addition, no participant cited preference for continuous exercise compared to either regime of interval training.

Significant differences in oxygen uptake (Fig. 1A) and blood lactate concentration (Fig. 2) between HIIT/SIT and CEX confirm the greater metabolic strain of interval training versus continuous exercise. Data from a study in young able-bodied adults[31] also showed higher BLa and VO_2 in response to high volume HIIT versus 20 min of CEX. The greater oxygen uptake seen in both interval training regimes reflects higher reliance on oxidative metabolism for ATP supply; whereas, greater recruitment of higher threshold fast twitch muscle fibers and subsequent reliance on glycolysis mediate the significantly higher BLa observed in response to HIIT and SIT versus CEX. Our perceptual findings also parallel recent data exhibited in active and untrained adults. In active men, Bartlett *et al.*[21] demonstrated higher enjoyment measured via PACES in response to interval running (6×3-minute bouts at 90% VO_2max separated by 3 minutes recovery at 50% VO_2max) versus 50 min of running at 70% VO_2max. Bouts were matched for average heart rate, oxygen uptake, and total energy expenditure although RPE was higher in response to interval running. In untrained men and women, Jung *et al.*[22] compared affective and enjoyment responses between HIIT (1 minute at 100% Wpeak separated by 1 minute at 20% Wpeak) and moderate (40 minutes at 40% Wpeak) and heavy CEX (20 minutes at 80% Wmax). Results showed significantly lower affect in response to HIIT and heavy CEX versus moderate CEX, which adheres to the Dual-Mode theory.[12] Yet, perceived enjoyment was similar between HIIT and moderate CEX, and when asked which exercise mode was preferred, 60% chose HIIT and 30% chose moderate CEX. Similar findings were also exhibited by Martinez *et al.*[32] who showed that shorter bouts of HIIT led to more positive affect than heavy CEX. So, despite the greater VO_2, BLa, and HR evoked by HIIT and SIT (Figs. 1 and 2), it is not viewed as more unpleasant than moderate or heavy CEX.

Several explanations have been identified to explain the greater enjoyment seen in response to HIIT compared to CEX. One explanation is the unique structure of HIIT consisting of brief, intense bursts of exercise separated by recovery.[22] It is thought that these frequent breaks reduce participants' perception of difficulty and increase feelings of pleasure of this modality. In addition, completion of each bout of HIIT provides a sense of accomplishment that does not occur in CEX until the completion of the entire bout.[22] Lastly, the lower total exercise volume of HIIT and especially SIT may reduce perception of difficulty and increase feelings of pleasure. Overall, HIIT and SIT do not seem to cause severely negative perceptions in individuals unaccustomed to intense exercise, and may in fact augment perceptual responses versus more prolonged bouts of exercise during which effort must be sustained over extended periods.

To our knowledge, only two studies have explored efficacy of chronic HIIT in this population. Brurok *et al.*[23] required six men with chronic complete SCI to perform 24 sessions of hybrid HIIT at intensities equal to 85–90% Wpeak from arm ergometry and current amplitude of 80% of 140 mA during FES cycling. VO_2peak was increased by 24.4% which was mediated by a significant increase in stroke volume. In response to 6 weeks of virtual reality hybrid HIIT, a 20% increase in VO_2peak was shown.[24] These findings suggest that HIIT is feasible in this population. Nevertheless, in neither study were perceptual or acute physiological responses examined, and no comparison was made to continuous exercise. Consequently, these data leave much to be clarified regarding suitability of HIIT in persons with SCI.

Data regarding changes in oxygen uptake (Fig. 1A), heart rate (Fig. 1B), and blood lactate concentration (Fig. 2) confirm the strenuous nature of HIIT and SIT performed in the current study. Oxygen uptake attained 82% and 90% of VO_2peak during SIT and HIIT. Peak HR during HIIT (160.1 ± 31.1 b/minute) and SIT (159.6 ± 30.2 b/minute) was comparable to peak HR from the baseline graded exercise test (160.6 ± 29.1 b/minute) demonstrating the significant cardiovascular stimulus of our interval training regimes. In fact, these HR values are higher than those seen for combined arm and leg cycling at 80% HRpeak.[33] Peak BLa was equal to 7.6 ± 3.3 and 9.0 ± 3.0 mM in response to HIIT and SIT which were higher than that determined at 75% and 100% of CEX (4.2 ± 1.4 mM and 3.6 ± 1.2 mM). Previous findings[32] show slightly lower BLa values during steady state FES leg cycling in sedentary men with complete SCI compared to HIIT and SIT. In contrast, similar BLa values (6.4–8.5 mM) were demonstrated in nine men with chronic SCI performing steady-state arm ergometry combined with FES leg cycling, but completion of hybrid exercise on a commercially available arm and leg tricycle at intensity equal to 80% VO_2peak led to higher BLa (5.7–10.8 mM).[34] This marked production of BLa is surprising considering that our participants were not using their lower extremity as is the case with FES cycling, although many of our participants with paraplegia attempted to engage their trunk musculature during sessions of HIIT or SIT.

Affect declined during all exercise modes (Fig. 4B) but was not different between CEX, HIIT, and SIT. This result is opposed by previous data[35] which demonstrated less positive affect during HIIT versus CEX. Similar data were shown by Jung *et al.*[22] in which affect was less positive in response to HIIT compared to moderate CEX, although responses were comparable between HIIT and vigorous CEX. An explanation for this may lie in the significant blood lactate accumulation seen throughout all exercise modes, which has been suggested to elicit reductions in affect.[12] In addition, arm ergometry may augment ability to express feelings of exertion during exercise compared to exercise involving large muscle groups.[36] Thus, the perceptual sensitivity for the processing of physiological information may be increased during small muscle mass exercise.[37]

There are a few limitations to the present study. Our sample was relatively small although it was diverse in age as well as injury severity and completeness which broadens our findings to a larger portion of individuals with SCI. Despite this, differences in outcome measures between exercise modalities were highly significant and parallel responses seen in able-bodied populations. Previous studies employing HIIT in this population[23,24] combined arm ergometry with lower-body FES, which would elicit a larger exercising muscle mass and higher absolute increases in VO_2 and HR. We acknowledge that HIIT and SIT as performed in the current study may not be feasible in persons with SCI lacking adequate upper body strength. The specific workload used to implement CEX equal to 45% Wpeak resulted in significant increases in BLa (Fig. 2), which suggests that it was more intense than work rates typically assigned for moderate continuous exercise. Nevertheless, HR, VO_2, and BLa were lower during CEX compared to HIIT/SIT, which emphasizes that it was substantially less strenous than acute interval training. It has been reported[12] that the time it takes for a significant increase in affect to occur once exercise ceases may take longer following more intense exercise such as HIIT while the influence of the interoceptive cues dissipates, so our reported values recorded immediately after each HIIT/SIT bout should be similar to those taken during exercise. Lastly, our sample was habitually active, so data cannot be applied to persons with SCI who are sedentary. However, our mean VO_2max was considerably lower than average values (VO_2peak = 1.51 L/minute) previously reported in persons with SCI.[38]

Conclusion

Our findings demonstrate that acute sessions of low-volume HIIT and SIT are more enjoyable than CEX despite a higher oxygen uptake, heart rate, and blood lactate concentration, indicating a substantially greater cardiorespiratory and metabolic stress. Moreover, as no side effects were reported and participants preferred interval training versus CEX, its potential as an element of exercise-based rehabilitation in persons with SCI should be further explored. As adaptations including VO_2peak may be maximized by training at a higher intensity of VO_2peak,[39] chronic interval training may serve as a robust and time-efficient approach to augment cardiorespiratory fitness and health status in this population who face elevated risks of chronic disease.

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Disclaimer statements

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Conflict of interest No author had any conflict of interest in the completion of this work.

Ethics approval None.

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